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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/080,714	02/25/2002	Alexander Jan Carel De Vries	105531.01	9142

7590 09/01/2004

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EXAMINER	
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ART UNIT	**PAPER NUMBER**
3644	#21

DATE MAILED: 09/01/2004

Please find below and/or attached an Office communication concerning this application or proceeding.

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EXAMINER

ART UNIT	PAPER

21

DATE MAILED:

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Commissioner for Patents

In response to the remand of May 7, 2004, attached is a copy of the translation of Japanese Published Unexamined Patent Publication No. H4-321816.

Attachment: Translation of H4-321816

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SUPERVISORY PATENT EXAMINER

Trinh Nguyen
Examiner 3644

PTO: 2004-3764

Japanese Published Unexamined (Kokai) Patent Publication No. H4-321816; Publication Date: November 11, 1992; Application No. H3-86711; Application Date: April 18, 1991; Int. Cl.^{5}: F16C 33/62 33/32 33/58 33/66; Inventor: Toru Mayumi; Applicant: NTN Corporation; Japanese Title: Herikoputaa no Giabokkusuyou Jikuuke (Bearing for Gearbox of Helicopter)

[Title of Invention]

Bearing for Gearbox of Helicopter

[Abstract]

[Purpose]

To improve an oil film forming ratio for a bearing for a gearbox of a helicopter and extend the usable life.

[Constitution]

As in a bearing used for a gearbox of a helicopter, a large number of independent small recesses are randomly provided on the surface of a rolling element of the bearing or at least one of the rolling surfaces of inner and outer bearing rings to control the roughness of this slightly rough surface. By these means, it becomes advantageous to form an oil film between the bearing rings and the rolling element, thereby eliminating abrasion and peeling damage and thus extending the usable life.

[Claim(s)]

[Claim 1]

A bearing for a gearbox of a helicopter, characterized in that a large number of independent fine recesses are randomly provided on the surface of a rolling element of the bearing or at least one of the rolling surfaces of inner and outer bearing rings to make the parameter SK value of the roughness of the recess provided surface negative and to obtain a 10 to 40% area ratio of the fine recesses occupied on the surface.

[Claim 2]

The bearing for the gearbox of the helicopter, as disclosed in Claim 1, characterized in that the average area of the fine recesses is 35 to 150 μm^2 when arranging by eliminating a 3 or less $\mu m \phi$ equivalent circle diameter.

[Detailed Description of the Invention]

[0001]

[Field of Industrial Application]

This invention pertains to a bearing for a gearbox of a helicopter.

[0002]

[Prior Art]

As shown in Fig.11, as for a gearbox 1 of a helicopter, the rotation of an input shaft 2 to be connected to a jet engine is transmitted to an output shaft 3 by various gears. Various gears 4 are incorporated and used to support input shaft 2 and output shaft 3, such as a cylindrical roller bearing, a cone-shaped roller bearing, a spherical roller bearing, a ball bearing and the like.

[0003]

A lubricant is necessary to be supplied to each bearing 4. Since gearbox 1 of the helicopter is connected to the jet engine, the same lubricant as that for the jet engine is used for gearbox 1.

[0004]

As for a lubricant for the jet engine, synthetic oil at a low viscosity is used because of a necessity in operation in cold places and a lubricating characteristic at high temperatures.

[0005]

[Problem to Be Solved by the Invention]

As the jet engine is driven at a high speed rotation and a lower load, an oil film forming between bearing rings and a rolling element is possible for a bearing inside the jet engine even if synthetic oil at a low viscosity is used. No problem occurs on the durability of the bearing.

[0006]

On the other hand, bearing 4 inside gearbox 1 is often used at a low speed and a higher load. When bearing 4 at these conditions is lubricated with the low viscosity synthetic oil, the oil film forming between the bearing rings and the rolling element becomes insufficient to generate abrasion, a peeling, peeling damage and the like, thereby reducing the usable life of the bearing.

[0007]

According to the aforementioned problem of prior art bearing, the objective of the invention is to offer a bearing for a gearbox of a helicopter that is capable of advantageously forming an oil film between bearing rings and a rolling element even if synthetic oil at a low viscosity is used and extending the usable life of the bearing.

[0008]

[Measures for Solving the Problem]

In order to eliminate the problem as mentioned above, the invention adopts a constitution as in a bearing for a gearbox of a helicopter, such that a large number of independent small recesses are randomly provided on the surface of a rolling element of the bearing or at least one of the rolling surfaces of inner and outer bearing rings to make the parameter SK value of the roughness of the recess provided surface negative and to obtain a 10 to 40% area ratio of the fine recesses occupied on the surface.

[0009]

[Effect]

As a large number of the independent small recesses are randomly provided on the surface of the rolling element of the bearing or at least one of the rolling surfaces of the inner and outer bearing rings to make the parameter SK value of the roughness of the recess provided surface negative and to obtain the 10 to 40% fine recess occupying surface area ratio, the fine recesses function as lubricant collecting locations and supply

buckets to the contact sections, thereby improving the oil film formation between the bearing rings and the rolling element. No abrasion, peeling and peeling damage occur. Subsequently, the usable life of the bearing for the gearbox of the helicopter is extended.

[0010]

[Working Example]

The working example of the invention is described based on the attached drawings.

[0011]

Fig.1 illustrates a cylindrical roller bearing 11 as the bearing for the gearbox of the helicopter as shown in Fig.11, which has a structure with a large number of cylindrical roller rolling elements 14 incorporated in between an inner ring 12 and an outer ring 13.

[0012]

Fig.2 illustrates a ball bearing 15, which has a structure with a large number of steel ball rolling elements 18 incorporated in between an inner ring 16 and an outer ring 17.

[0013]

As in cylindrical roller bearing 11 and ball bearing 15, numerous independent fine recesses are randomly provided on the surfaces of rolling elements 14 and 18 or at least one of the rolling surfaces of inner rings 12 and 16 and outer rings 13 and 17 to form a

slightly rough surface. The slightly rough surface has a negative parameter SK value of the surface roughness, for example, at –1.6 or lower.

[0014]

At a surface processing for obtaining the aforementioned conditions for the surface roughness, a desired finish surface is obtained by a special barrel polishing means.

[0015]

The parameter SK value refers to a distortion level (SKEWNESS) of a surface roughness distribution curvature. The SK value of a symmetrical distribution such as a Gaussian line becomes 0. However, at a predetermined SK value at –1.6 or lower, the shape and distribution of the surface recesses is within the range that is advantageous to form an oil film.

[0016]

In the case of the surface of cylindrical roller rolling element 14 and the rolling surfaces of inner rings 12 and 16 and outer rings 13 and 17, the parameter SK value of the slightly rough surface is –1.6 or lower in both shaft and circumferential directions.

[0017]

Whereas the area ratio of the fine recesses occupied on the slightly rough surface is in the range of 10 to 40%, the average area of the fine recesses is 35 to 150 μm^2 when arranging by eliminating a 3 or less $\mu m\phi$ equivalent circle diameter.

[0018]

Fig.3 illustrates a finish surface state of a reference roller, and Fig.4 a finish slightly rough surface state processed on the surface of a rolling element or the rolling surfaces of inner and outer rings. As shown in Fig.4, the slightly rough surface of the invention forms recesses on a plane and is a special surface so that protrusions do not occur on the plane.

[0019]

In order to quantitatively measure the fine recesses, the surface of the rolling element or the rolling surfaces of the inner and outer rings are enlarged. Using the image of the enlarged surface, the fine recesses are quantified by using an image analysis system.

[0020]

At the analysis, a white portion on the image is defined as a flat surface section, and a black portion as fine recesses. For example, when an analysis is performed using an LA-525 image analysis system produced by Pias Corporation, the brightness of the original image is first cleared with a highlighting filter. The very fine recesses at a 3 or less μmϕ equivalent circle diameter as the black portion are then removed using a noise eraser.

[0021]

The size and distribution of the remaining fine recesses after the removal with the noise eraser and the surface area ratio thereof are obtained to evaluate the surface of the rolling element or the rolling surfaces of the inner and outer rings.

[0022]

Next, the result of a longevity test conducted using prior art ball bearing and a ball bearing of the invention is described. Prior art ball bearing is obtained by applying a super finishing onto the surfaces of the inner and outer rings and the surface of the steel ball rolling element. The ball bearing of the invention is obtained by applying the super finishing onto the surfaces of the inner and outer rings and providing recesses onto the surface of the steel ball rolling element in a random direction to form a slightly rough surface.

[0023]

The super finish surfaces of the inner and outer rings and the steel ball rolling element are 0.2 μmRmax or less, and the slightly rough surface in the random direction 2 μmRmax.

[0024]

A radial load testing machine 21 as illustrated in Fig.5 by a schematic diagram is used as a testing device for the working example. The test is conducted while attaching a testing bearing A to a rotating shaft 22 and adding a load.

[0025]

The testing conditions are as follow.

[0026]

Radial load	500 Kgf
Rotating speed	3500 rpm
Lubricant	Turbine oil

The result of a rolling element longevity test conducted to each testing bearing at the above conditions is indicated in Fig.6.

[0027]

As is clear in the result of the above test, a 10% damage possibility of the ball bearing of the invention is at 125 hours, which indicates a significantly long usable life in comparison with that of prior art ball bearing at 45 hours.

[0028]

Generally, there is a relation between an oil film parameter and an oil film forming ratio as illustrated in Fig.7. It is said that the oil film parameter is preferably larger in terms of the usable life. However, as is clear in the result of the longevity test, it cannot be unconditionally explained by Λ alone.

[0029]

An acceleration peeling test is conducted on identification of the oil film forming state on the finish surface of the steel ball rolling element and the peeling resistance using a cylindrical testing piece having a finish surface as similarly to that of the testing bearing steel ball of the invention or prior art testing bearing steel ball at a free rolling condition

using a double-cylinder testing machine. The identification of the oil film forming state is made by a direct current conduction means.

[0030]

Testing conditions:

Maximum contact surface pressure	227 Kgf/mm2
Circumferential speed	4.2 m/sec (2000 rpm)
Lubricant	Turbine oil
(10 cst at the testing conditions)	
Number of charges repeated	4.8×10^5 (4 hr)

The oil film forming ratios by the testing are as indicated in Fig.8 and Fig.9. The oil film forming ratio on the finish surface of the testing bearing of the invention improves about 20% at a starting of the operation in comparison with that of prior art testing bearing.

[0031]

It is identified that the finish surface testing piece of the invention almost completely forms an oil film at repeated charges at 1.2×10^5.

[0032]

Furthermore, occurrence and development of a large number of peelings of an about 0.1 mm length are identified on the finish surface of prior art testing bearing. In contrast, no damage is identified on the finish surface of the invention.

[0033]

As described above, in comparison with the rolling of the bearing ring and the steel ball rolling element having the regular super finish surfaces, the ball bearing of the invention having the super finish bearing ring and the fine recesses provided on the steel ball rolling element is capable of increasing the thickness of the oil film if numerous fine recesses a function as lubricant collecting places and supply buckets to the contact sections and if the direction of the surface roughness is perpendicular to an oil b flowing direction, as shown in Fig.10 (A) and (B).

[0034]

For these reasons, as in a bearing for a gearbox of a helicopter that uses synthetic oil at a low viscosity as a lubricant also, the oil film forming ratio between the bearing ring and the rolling element improves, thereby extending the usable life of the bearing.

[0035]

When the area ratio of the fine recesses is 30% or greater and when the average surface is 120 μm^2, the contact effective length is reduced to deteriorate the effect of the extended usable life.

[0036]

As the working example exemplifies the cylindrical roller bearing and the ball bearing as indicated in the drawings, it is also applied to all types of bearings used for the

gearbox of the helicopter, such as a cone-shaped roller bearing, a spherical roller bearing and the like.

[0037]

[Effect]

As described above, according to the invention, as in the bearing incorporated into the gearbox of the helicopter, the randomly slightly rough surface is formed on the surface of the rolling element or at least one of the rolling surfaces of the inner and outer rings. The parameter SK value of the surface roughness is made negative, and the surface area ratio of the fine recesses occupied is made 10 to 40%. By these means, the oil film forming on the rolling surface becomes advantageous. Even if the lubricant is synthetic oil at a low viscosity, the thickness of the oil film between the bearing rings and the rolling element is increased, thereby preventing the generation of abrasion and peeling damage and thus extending the usable life of the bearing for the gearbox of the helicopter.

[Brief Description of the Invention]

[Fig.1]

Fig.1 is a cross-sectional view illustrating a cylindrical roller bearing.

[Fig.2]

Fig.2 is a cross-sectional view illustrating a ball bearing.

[Fig.3]

Fig.3 is a schematic diagram illustrating a finish surface of prior art rolling element.

[Fig.4]

Fig.4 is a schematic diagram illustrating a finish surface of a rolling element of the invention.

[Fig.5]

Fig.5 is a schematic diagram illustrating a testing device.

[Fig.6]

Fig.6 illustrates a graph that indicates the results of a longevity test.

[Fig.7]

Fig.7 illustrates a relation between the oil film parameter and the oil film forming ratio.

[Fig.8]

Fig.8 illustrates a graph that indicates the oil film forming ratio of prior art ball bearing.

[Fig.9]

Fig.9 illustrates a graph that indicates the oil film forming ratio of a ball bearing of the invention.

[Fig.10]

Fig.10 (A) and (B) are schematic diagrams illustrating a slightly rough surface and the flow of oil.

[Fig.11]

Fig.11 is a schematic diagram illustrating a gearbox of a helicopter.

[Description of the Reference Numbers]

11...Cylindrical roller bearing

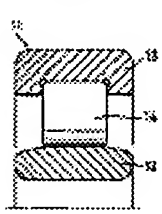
12 and 16...Inner rings

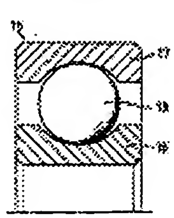
13 and 17...Outer rings

14...Cylindrical roller rolling element

15...Ball bearing

18...Steel ball rolling element





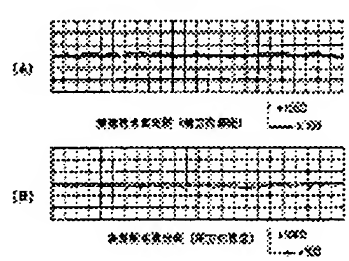
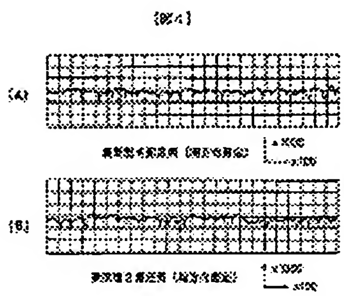


Fig.3 (A):

Horizontal axis: Surface roughness measuring example (measurement in the axial direction)

Fig.3 (B):

Horizontal axis: Surface roughness measuring example (measurement in the circumferential direction)



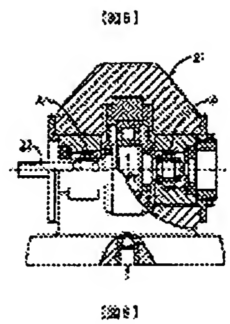
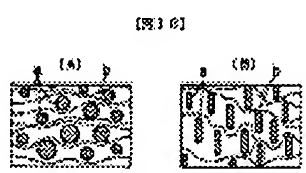


Fig.4 (A):

Horizontal axis: Surface roughness measuring example (measurement in the circumferential direction)

Fig.3 (B):

Horizontal axis: Surface roughness measuring example (measurement in the axial direction)



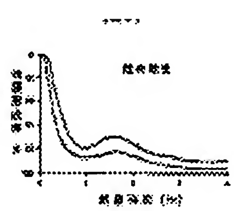
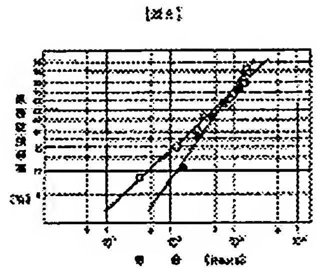


Fig.8:

Prior art bearing

Vertical axis: Oil film forming ratio

Horizontal axis: Testing period



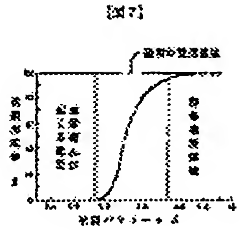


Fig.6:

Vertical axis: Accumulative damage probability

Horizontal axis: Usable life

Fig.7:

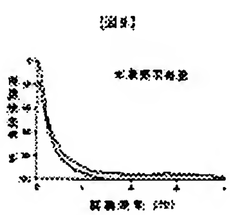
Vertical axis: Oil film forming ratio

Horizontal axis: Oil film parameter Λ

Left column: Damage occurring range on the surface

Middle column: Regular usage region

Right column: Longevity extending region



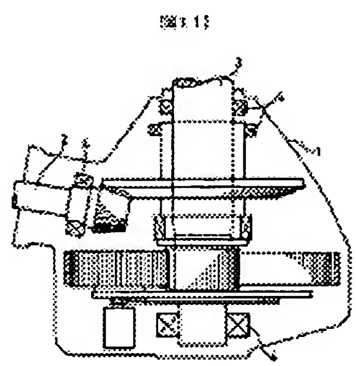


Fig.9:

Bearing of the invention

Vertical axis: Oil film forming ratio

Horizontal axis: Testing period

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